Feature

Supercomputer Simulates Hyakutake

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A supercomputer simulation of Comet Hyakutake's interaction with the solar wind demonstrates that resulting X-ray emissions can be used to monitor comets and solar wind phenomena, NASA-funded researchers write in the current issue of *Science*. The simulation was conducted using an Earth sciences supercomputer at the Goddard Space Flight Center (GSFC). The results match and explain March 27, 1996, observations of Comet Hyakutake by Germany's ROSAT satellite, the first detection of X-ray emissions from any comet. The model also supports a leading theory for how the X-rays are generated.

The theory

"Cometary X-rays present a potentially powerful new tool to monitor comet activity far from Earth, as well as the composition and flux of the solar wind," said the *Science* article co-author Tamas Gombosi of the University of Michigan. "By capturing these X-rays' detailed energy spectrum, it might be possible to monitor the propagation and evolution of spectacular solar wind phenomena, such as the coronal mass ejections seen this January and April."

About one percent of the solar wind, which flows from the Sun out past Pluto, is composed of minor ions; atoms (such as oxygen, carbon and neon) that have been nearly stripped of their electrons and thus have a high positive charge. Thomas Cravens of the University of Kansas theorizes that these minor ions steal electrons from neutral atoms and molecules of cometary origin. The electrons are first seized in excited states, traveling in the ions' outer orbitals. As the electrons fall to lower orbitals, Cravens' theory asserts that X-rays are emitted, in addition to other forms of radiation.

"Considering the magnitude and shape of the emission, we believe the most satisfactory theory to be this mechanism of charge exchange excitation," Gombosi said. "Other explanations produce neither the crescent pattern nor the intensity observed by ROSAT and duplicated by our simulation."

Within this pattern, some electron orbital transitions emit distinct wavelengths of X-rays that can be measured. The computer simulation shows that the overall X-ray spectrum for Comet Hyakutake depends mainly on the solar wind composition, and not on the comet. Because of this independence, researchers can determine the relative size of the comet's atmosphere from the proximity of the brightest X-rays to the icy nucleus.

"In Hyakutake, the brightest X-ray region was 18,700 miles (30,000 kilometers) ahead of the comet, on the Sun side," said University of Michigan co-author Michael Combi. "If the comet has enough of an atmosphere, the solar wind minor ions recombine with electrons far from the nucleus. If the comet were producing less atmospheric gas, the place of maximum emission would be closer to the nucleus," Combi said.

Testing the theory

This theory will also be tested on Comet Hale-Bopp, which is scheduled to be observed by Japan's ASCA X-ray satellite this September. "Comet Hale-Bopp should have the emission shifted further sunward; it is bigger than Hyakutake," Combi said.

Active comets are typically first observed in visible light at large distances from the Sun. After discovery, the orbits of comets can be established with very high accuracy as they pass through the inner solar system. "If X-rays are observed from the known location of a comet, one can conclude with great confidence that the X-rays originated from the comet," Gombosi said.

The University of Michigan team used March 27, 1996, solar wind density measurements from NASA's **WIND** spacecraft. Their model first considers the global interaction of the solar wind with the comet. It projects the comet into a three-dimensional grid that automatically applies finer resolution where more activity occurs. This physics component predicts the deflective paths and speed of the solar wind traveling through the comet.

Simulation images are available on the World Wide Web at:

http://hpcc.engin.umich.edu/HPCC/recent3/index.html

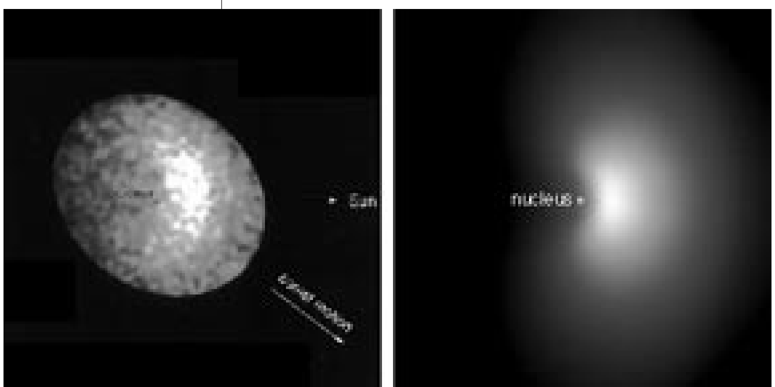

Image (A) of the X-ray emission from Hyakutake, measured by the ROSAT HRI on 27 March 1996. Computed image (B) of sum of all emission lines in the HRI passband caused by the charge exchange of solar wind ions with cometary gas. In both images, the X-ray emission shows a crescent shape and the maximum of the emission is displaced Sunward from the nucleus.The scale of both images is the same.

Acknowledgments

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